SPATIAL DISTRIBUTION PATTERN OF SUCKING PESTS ON PROMISING SUNFLOWER LINES (*Helianthus annuus* L.)

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ABSTRACT

One hundred and twelve accessions of sunflower (*Helianthus annuus* L.) were screened under field conditions in two seasons at Sambavar Vadakarai and Udappankulam villages of Tirunelveli district of Tamilnadu, India during January to April and June to September, 2016. Investigations were made to study the distribution pattern of pests viz., whiteflies (*Bemisia tabaci*), leaf hoppers (*Amrasca biguttula biguttula*) and thrips (*Thrips palmi*) on sunflower. Studies on spatial distribution of the above pests revealed a negative binomial distribution and aggregated nature on sunflower. Intra-plant distribution studies indicated that middle strata of sunflower recorded least relative variation for whiteflies and hence provided Host reliable estimate of their population. With regard to leaf hoppers, based on least relative variation, lower strata was best suited for estimating population on sunflower. The upper strata recorded least relative variation for thrips and thus provided a reliable population estimate.

In field screening, out of 112 accessions of sunflower, six accessions (KBSH-1, K 578, AHT 02, IHT 751, GMU 615, GHU 631) were identified to be comparatively resistant to the sucking pests. The check variety 'Morden' proved to be the most susceptible sustaining highest populations of sucking pests throughout the experimental period. Studies on spatial distribution of sucking pests of sunflower were conducted and inferred with distribution pattern with the aid of stastical tests. The results revealed that the population of whiteflies fitted negative binomial model and the distribution was aggregated. Leaf hoppers have also exhibited aggregated distribution on sunflower and the population fitted negative binomial model. Thrips have shown aggregated distribution and negative bionomial model fitted the population pattern. Intra-plant distribution studies revealed that leaf hopper population preferred lower and middle canopy compared to upper canopy.

Keywords: *Helianthus annuus* – Field screening – Sucking Pests - Spatial Distribution

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is an important edible oil seed crop in India, being cultivated in an area of 14 lakh hectares with a production of 8.23 lakh tonnes and productivity of 701 kg/ha in 2009- 2010 (Anonymous, 2011). The productivity of this crop is affected by several biotic and abiotic constraints. Many insecticides are being used to control the pest complex of sunflower, which pose health hazards and environmental problems. Plant resistance is a potential alternate management strategy to reduce such pest damage, since it is eco-friendly, cost effective and can be integrated with cultural and biological control measures

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(Anitha Chirumamilla *et al*., 2010).

Whiteflies (*Bemisia tabaci*), leaf hoppers (*Amrasca biguttula biguttula*) and thrips (*Thrips palmi*) are the important sucking pests of sunflower in India (Rana and Sheoran, 2004). Both nymphs and adults suck the plant sap and their severe infestation leads to curling of leaves and the characteristic "hopper burn" symptom. Sucking pests infestation reduces the oil yield. Since host plant resistance can be effectively exploited and utilized against sucking pests (Saritha *et al*., 2008), the present investigation was undertaken to screen sunflower germplasm for resistance against leaf hopper under field conditions.

MATERIALS AND METHODS

One hundred and twelve accessions of sunflower obtained from various sources were screened for their resistance against leaf hopper (*A. biguttula biguttula*). Two field experiments were conducted during January to April and June to September, 2009 respectively at Sambavar Vadakarai and Udappankulam villages of Tirunelveli district of Tamilnadu, India. Sunflower seeds were sown on the ridges at a spacing of 45 X 30 cm. Ten plants were maintained per row. A known susceptible check 'Morden' was maintained @ one row for every five rows of the test accessions as infestor rows. Two rows of the susceptible check were also maintained around the experimental field as infestor crop. Three replications were maintained per accession. Recommended agronomic practices were followed except plant protection measures.

Observations on incidence of thrips, whiteflies and leaf hoppers were made at weekly intervals starting from the appearance of individual pests upto flowering.

The sucking pests *viz.*, whiteflies, leaf hoppers and thrips were counted on two top, two middle and two bottom leaves of the plant canopy, on 30 randomly selected plants (Mahto, 1990; Men and Strode, 1999 and Rathore and Tiwari. 1999). The observations were made during early hours of day when there was minimum movement of these sucking pests. Each leaf was slowly turned back and observed to take the count of both nymphs and adults of whitefly. Later the leaves were gently tapped on a tray lined with white paper and the thrips (nymphs and adults) population, were counted.

Inferring Distribution Pattern with aid of Statistical Tests

The first step in confirming the nature of distribution was to arrange the data in frequency distribution. Mean and variance were then worked out (Snedecor and Cochran, 1967).

On the basis of ($\bar{X}$) ~~and~~ S^2, statistical tests was applied to confirm distribution of leaf hoppers, whiteflies and thrips. The intra-plant distribution was studied by applying the following statistical methods.

Variance - Mean Ratio (S^2- x Ratio)

The data of leaf hoppers, whiteflies and thrips population was summarized in frequency distribution. The figures were arranged in numerical order and grouped into frequency classes and plants (No.) that fall into each class (f) was recorded. The model for the above frequency was fitted as per the procedure given by Elliott (1979). The mean ($\bar{X}$) and variance (S^2) was calculated for each set of observations following the statistical procedures. The

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distribution pattern was indicated random if $S^2 = \bar{X}$, aggregated if $S^2 > \bar{X}$ and regular if $S^2 < \bar{X}$.

Chi-Square (χ^2) Test for "Goodness-of Fit" for Agreement with a Negative Binomial Distribution.

The fitting of negative binomial requires discrete frequency classes individuals starting from zero onwards.

The data competitor for each week was subjected to Chi-Square test for "goodness-of-fit" for agreement with a negative binomial distribution. The observation and expected frequencies were compared by

$$\chi^2 = \frac{\text{Observed frequency} - \text{Expected frequency}}{\text{Expected frequency}}$$

The number of degrees of freedom, v = (number of frequencies for the week - number of parameters estimated - 1). In a negative binomial distribution, two parameters, [arithmetic mean ($\bar{X}$) and variance (S^2)] were estimated from the data and, therefore,

V = (number of frequencies) - 3

The data was accepted at 95 percent probability (P>0.05) on the the hypothesis

H_0= The given data does not follow negative binomial distribution. H_1 = The given data follows negative binomial distribution. Due to some chance factor, the comparison between the actual and expected frequencies may be distorted by irregularities. Hence two alternativetests, based on the difference between the actual and expected moments mean, variance or skewness can be compared with their standard errors (Anscombe,1950; Bliss and Fischer, 1953).

Determination of Dispersion Parameter 'K'

The parameter 'K' which gives the degree of aggregation in the natural population was calculated. A negative binomial series $(q-p)^{-k}$ has mean kp and a variance kpq, therefore, q-k_{pq}/k_p since q-p = 1, hence p = q-l and

$$K \frac{k_p}{P} \text{ ------ } \frac{k_p}{q-1} \quad \frac{K_p}{\frac{K_{pq}}{Kp}-1} \quad \frac{K_p}{\frac{K_{pq}-K_p}{Kp}} \quad \frac{K_p \text{ x } K_p}{k_{pq}-K_p}$$

$$= \frac{\bar{X} \text{ x } \bar{X}}{S^2 - X} \qquad = \frac{X^2}{S^2 - \bar{\bar{X}}}$$

By using this procedure, 'K' values (moment estimate of 'K') for each of the 5 sets (starting from 35 DAS to 63 DAS at weekly interval) for whiteflies, leaf hoppers and thrips were calculated for Rabi and Rabi-summerseasons, respectively.

Other methods of calculating 'K' were also used.

Estimation of 'K' from Proportion of Zeroes

$$\text{Log } \frac{N}{n_0} = \text{K log } (1 + \frac{\bar{X}}{K})$$

Where, N = total number of sampling unit.

n_0 = Number of sampling unit containing no population (Whiteflies, leafhoppers and thrips)

K = K value obtained from moment estimate

This method of calculating ‘K’ was done in those weeks only, when zero population of whiteflies, leaf hoppers and thrips were noticed during sampling.

Trial and Error (Iterative) Method

This method was taken up for every week of sampling

$$N \log_e \frac{(1+\overline{X})}{K} = \frac{\sum (A\text{x})}{K+\text{x}}$$

Where Log_e = Napaerian log

A_x = The sum of all frequencies of sampling units containing more than x individuals.

The value of ‘K’ obtained by this method was treated as real andaccurate ‘K’ value.

Determination of Common ‘K’ (Kc)

The value of common ‘K’ for the upper, middle and lower strata during both the seasons was computed by following moment and regression method of Bliss and Fischer (1953). The two statistics required (X' Y') were calculated as follows.

$X' = (\overline{X})^2 - S^2 / N$

$Y' = S^2 - \overline{X}$ where,

$\overline{X}$ = Mean

S^2 = Variance

N = Number of plants on which X is based

The common 'K' (K_c) is estimated by

$K_c = \frac{X'}{Y'}$

Indices of Dispersion

The Poisson distribution, resulting from random dispersion, makes a useful yard stick by which the actual distributions were compared. As an alternative to random dispersion, insects were usually grouped to a certain extent, so the scatter values tend to be increased by aggregation. Different indices to compare the different patterns of dispersion in population. The following indices of dispersion were calculated.

A. Cole’s Index (Cole, 1946)

Cole’s Index value has only empirical basis and is not independent of number of observations. It is calculated by the formula,

$$\text{Cole's Index} = I = \Sigma(X)^2 / \Sigma X)^2$$

B. Lloyd's Index of mean crowding (Lloyd, 1967)

"Index of mean crowding" to measure intensity of interaction experienced between individuals and is formulated by

$$X^* = X + \frac{X}{K}$$

The ratio of mean crowding the mean density $\frac{X^*}{K}$ measures patchiness and was termed as "Patchiness index".

$$X^* / \overline{X} = 1 + 1/K$$

The "Patchiness index" describes "how many times as crowded an individual (in an average as it would be) if the same population had a random distribution". The value of patchiness index was calculated by dividing the mean crowding by mean density for each set of observations. The value of index is ≤ unity in regular and random distribution" whereas > unity in ease ofcontagious (over dispersed) distributions.

RESULTS

To establish the distribution pattern of whiteflies, leaf hoppers and thrips infesting sunflower population counts were taken on upper, middle and lower strata from 30 plants (Rabi and Rabi-Summer, 2016-17) at weekly interval starting from the first incidence of the pests. The data was arranged in frequency distribution. The mean ($\overline{X}$), Variance (S^2), dispersion parameters (K) and indices of dispersion, were also worked out.

Variance - Mean Ratio

Whiteflies

The variance to mean ratio ($S^2/\overline{X}$) were estimated for the whitefly populations during rabi and rabi-summer seasons and the results are presented in Table 1 and Table 1a.

Upper Strata

The value of variance to mean ratio calculated during Rabi ranged between 1.28 and 2.01. During rabi-summer, incidence of whiteflies was not noticed upto 35 DAS. For the remaining crop growth period, the ratio was inbetween 1.27 and 2.02. As the values of index of dispersion were greater than unity, it indicated aggregated nature of whiteflies.

Middle Strata

The middle strata recorded in between 1.12 to 1.89 during rabi and 1.09 to 1.67 during rabi-summer. The aggregated nature of whiteflies is well illustrated by greater than unity values in all observations.

Lower Strata

During rabi, the ratio in the lower strata was the highest (2.06) at 56 DAS and least (1.20) at 49 DAS. However the values were always greater than one. The variance to mean ratios calculated for rabi-summer were also greater than unity (1.27 to 1.70). These observations invariably indicate aggregated distribution.

Leaf hoppers

The ratios of variance to mean ($S^2/\overline{X}$) were calculated for the leaf hopper populations at different crop ages during rabi and rabi-summer seasons and the results were tabulated (Table 2 and Table 2a).

Upper Strata

During rabi, leaf hoppers was not noticed at 35 DAS and 63 DAS. The ratio was 1.17, 2.90 and 1.58 at 42, 49 and 56 DAS, respectively. In rabi-summer, the crop was free from leaf hoppers upto 49 DAS. The ratio of variance to mean was 1.65 at 56 DAS and 1.99 at 63 DAS. Since the values were greater than unity, it indicates aggregated nature of leaf hoppers.

Middle Strata

The ratio in the middle strata ranged from 1.08 to 1.58 during Rabi. Leaf hopper was not recorded at 35 DAS during Rabi-summer. The variance to mean ratio ranged between 1.47 and 1.79 from 42 DAS to 63 DAS. As all the values were greater than unity, the population shows aggregated distribution.

Lower Strata

During rabi, the ratio was in between 1.08 and 2.01. Leaf hopper was not noticed on rabi-summer crop at 35 DAS. The variance to mean ratios calculated for 42, 49, 56 and 63 DAS, ranged in between 1.47 to 2.56. The ratio was greater than unity in all the observations, which indicates aggregated population of leaf hoppers.

Thrips

The variance to mean ratio ($S^2/(\overline{X})$) were calculated for the thrips populations during rabi and rabi-summer seasons and the results were presented in Table 3 and Table 3a.

Upper strata

The upper strata recorded ratio ranged from 1.26 to 1.96 during rabi and 1.03 to 2.13 during rabi-summer. As the values were greater than unity, it indicates aggregated nature of thrips.

Middle strata

The variance to mean ratio of thrips in the middle strata ranged between 1.09 to 2.11 during rabi and 1.51 to 2.47 during rabi summer. As all the values were greater than unity, the thrips population shows aggregated distribution.

Lower Strata

No incidence of thrips was recorded on crop from 49 DAS to 63 DAS during both the seasons. At 35 DAS, the ratio was 1.70 in rabi and 2.03 in rabi-summer. At 45 DAS, ratio was 2.77 and 2.17 for rabi and rabi-summer, respectively. The values were greater than unity in all the observations, which indicates aggregated population of thrips.

Dispersion Parameters "K" of the Negative Binomial

The dispersion parameter was calculated by three methods. The K values obtained by trial and error method (K3) are treated as accurate values.

Whiteflies

The negative binomial nature of whiteflies was confirmed by calculating the value of dispersion parameter 'K' on the basis of mean (X) and variance (S^2) of each week following the methods explained in the previous chapter. The results are presented in Table 1. and Table 1a. for rabi and rabi-summer, respectively.

Upper strata

During rabi the value of dispersion parameter K_1 was least (0.88) at 63 DAS and highest (12.88) at 49 DAS. The K_2 values calculated from proportion of zeros ranged from 3.86 to 8.56 and the K_3 values were observed to be in between 4.54 and 7.33.

Whiteflies was not noticed at 35 DAS in rabi summer. For the remaining crop growth period, K_1, K_2, K_3 values ranged from 1.67 to 8.62, 7.75 to 8.33 and 3.70 to 7.43 respectively.

Thus, the K values calculated from trial and error method never went beyond 8, which confirmed aggregated distribution of whiteflies.

Middle strata

The values of dispersion parameter K (K_1) in the middle strata ranged between 2.97 to 18.31 for rabi and 4.20 to 9.10 for rabi-summer. The 'K_2' values were in between 3.87 to 8.59 for rabi and 7.75 to 8.33 for rabi- summer. In the trial and error method, the 'K' (K_3) value ranged between 3.67 to 6.77 for rabi and 3.60 to 7.47 for rabi-summer. As the 'K' values were never more than 8 in the accurate method, the aggregated distribution of whiteflies is confirmed.

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Lower Strata

During rabi, the values of dispersion K (K_1) ranged from 1.43 to 19.10 and the values were in between 2.56 and 6.23 for rabi summer. The 'K_2' values were in between 3.87 to 6.54 for rabi and 7.75 to 8.33 for rabi summer. The K_3 values ranged in between 4.00 to 7.32 for rabi and 4.18 to 7.94 for rabi-summer, which were always less than 8, indicating aggregation population of whiteflies on lower strata.

Leaf hopper

The negative binomial nature of leaf hoppers was confirmed by calculating the value of dispersion parameter 'K' on the basis of mean ($\bar{X}$) and variance (S^2) of each week. The results are presented in Table 2. and Table 2a. for rabi and rabi-summer, respectively.

Upper strata

No leaf hopper incidence was recorded on the upper strata at 35 DAS and 63 DAS during rabi. The K_1 values were 1.16, 0.10 and 1.61 at 42, 49 and 56 DAS, respectively. The K_2 values ranged from 4.51 to 5.14 from 42 DAS to 56 DAS. The K values calculated from trial and error method werein between 4.00 and 6.87.

During rabi-summer upto 49 DAS, there was no incidence of leaf hopper. At 56 DAS, the K_1, K_2 and K_3 values were 4.27, 6.53 and 4.26 respectively. The values of 1.79, 5.43 and 4.87 were arrived for K_1, K_2 and K_3 respectively at 63 DAS. Thus 'K' values never went beyond 8 in calculations from trial and error method confirming aggregate distribution of leaf hoppers in the upper strata.

Middle Strata

The value of dispersion parameter K (K_1) in the middle strata ranged between 1.43 to 20.00 for rabi and 1.97 to 4.72 for rabi-summer. The 'K_2' values were in between 4.50 to 5.78 for rabi and 5.13 to 7.62 for rabi- summer. In the trial and error method the 'K' (K_3) value ranged between 4.31to 5.35 for rabi and 4.46 to 7.62 for rabi-summer. As the 'K' values were never more than 8 in the trial and error method, the aggregated distributionof leaf hoppers is confirmed.

Lower strata

For the lower strata, the K_1 values ranged from 2.44 to 16.24 for rabi and 1.96 to 8.42 for rabi summer. The K_2 values were in between 4.54 and 5.78 for rabi and 6.35 and 7.72 for rabi summer. During rabi, the K_3 values ranged from 5.36 to 7.96 and for rabi-summer the values, ranged from 3.78 to 7.85. The K_3 values being always less than 8 indicated aggregated population of leaf hoppers on lower strata.

Thrips

The negative binomial nature of thrips was confirmed by calculating the value of dispersion parameter 'K' on the basis of mean (X) variance (S^2) of each week. The results are presented in Table 3. and Table 3a. for rabi and rabi-summer, respectively.

Upper Strata

The value of dispersion parameter K (K_1) ranged from 2.15 to 12.31 for rabi and 2.52 to 7.86 for rabi-summer. The K values calculated from proportion of zeroes (K_2) ranged from 5.09 to 7.94 for rabi and 6.42 to 7.69 for rabi-summer. The K values calculated from trial and error method (K_3) ranged from 4.38 to 7.60 for rabi and 4.08 to 8.00 for rabi-Summer. Thus 'K'values never went beyond 8 in calculations from trial and error method confirming aggregate distribution of thrips in the upper strata.

Middle Strata

For the middle strata the value of dispersion parameter K (K_1)showed a wide range of 0.94 to 49.50 for rabi. The values were ranging from 0.61 to 3.80 during rabi-summer. The 'K_2' values were in between 5.09 to 7.94 for rabi and 6.42 to 7.70 for rabi-summer. In the trial and error method, the 'K' (K_3) value ranged between 3.10 to 7.25 for rabi and 5.43 to 7.35 for rabi-summer. As the 'K' values were never more than 8 in the trial and error method, the aggregated distribution of thrips is confirmed.

Lower strata

No thrips were recorded on lower strata at 49 DAS and beyond, during both the seasons. The values of dispersion K (K_1) at 35 DAS and 42 DAS were 0.62 and 1.40 during rabi and 0.34 and 0.51 during rabi-summer. The K_2 values were in between 5.10 to 7.94 for rabi and 6.42 to 7.06 for rabisummer. The K_3 values ranged in between 5.75 to 5.94 for rabi and 7.10 to 7.19 for rabi-summer, which were always less than 8 indicating aggregate population of thrips on lower strata.

Common K (Kc)

The calculation of common K was done for upper, middle and lower strata during both the seasons to confirm the aggregated distribution of sucking pests.

Whiteflies

During rabi, upper, middle and lower strata recorded Kc values of 0.60,0.63 and 0.51 respectively. The Kc values during rabi summer were 0.45, 0.51 and 0.58 for the upper, middle and lower strata respectively. Since all the common K values were less than one, it indicated aggregated distribution of whiteflies (Table 1. and Table 1a.).

Leaf hoppers

The common K values for the upper, middle and lower strata during both the seasons were less than unity and thus the distribution of leaf hoppers was aggregated. The Kc values were 0.20, 0.85 and 0.35 for the upper, middle and lower strata respectively, during rabi. As per the data obtained during rabi-summer the computed Kc values were 0.51, 0.34 and 0.23, for upper, middle and lower strata, respectively (Table 2 . and Table 2a.).

Thrips

During rabi, the thrips population exhibited aggregated distribution as the Kc values of upper (0.38), middle (0.29) and lower (0.10) strata were never more than one. Similar results were obtained during rabi-summer also where upper, middle and lower strata recorded Kc values of 0.40, 0.31 and 0.37 respectively (Table 3. and Table 3a.).

Chi-Square Tests

The Negative Binomial nature of whiteflies, leaf hoppers and thrips was confirmed by subjecting population frequency, mean and variance data of these pests to Chi-square test.

Whiteflies

The negative binomial nature of whiteflies was confirmed by conducting Chi-Square test. The results are presented in Table 1. and Table 1a. for the two seasons rabi and rabi-summer, respectively.

Rabi

For the upper strata, the calculated values of Chi-Square ranged from 13.22 to 187.12. The values ranged from 5.79 to 138.73 for middle strata and 12.21 to 177.53 for lower strata. As the values were always greater than the table value of Chi-Square (1.96), it confirms negative binomial distribution of whiteflies.

Rabi-summer

The Chi-Square values ranged from 8.21 to 47.31, 20.78 to 59.23 and 13.20 to 62.69 for the upper, middle and lower strata, respectively. These Chi-Square values being greater than the table value (1.96), confirmed negative binomial distribution.

Leaf hoppers

The negative binomial nature of leaf hoppers was confirmed by Chi- Square test. The results are presented in Tables 2 . and 2 a . for the two seasons, rabi and rabi-summer, respectively.

Rabi

The calculated values of C hi-squares ranged between 2.12 to 14.16, 7.94 to 41.50 and 3.15 to 69.92 for upper, middle and lower strata respectively. These values were never less than the table values of Chi-Square (1.96), which confirmed negative binominal distribution of leaf hoppers.

Rabi-summer

Leaf hopper exhibited negative binominal distribution during rabi-summer also. As the calculated Chi-Square values were greater than table Chi-Square value (1.96). The calculated

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values of chi-squares ranged from 2.17 to 15.91, 2.71 to 31.03 and 2.79 to 57.84 for upper, middle and lower stratarespectively.

Thrips

The negative binomial nature of thrips was confirmed by conducting Chi-Square test. The results are presented in Table 3. and Table 3a. for the two seasons, rabi and rabi-summer, respectively.

Rabi

The upper strata recorded Chi-square values in the range of 18.88 to 160.16. The calculated values of Chi-square ranged between 14.05 to 151.22and 52.43 to 59.28 for middle and lower strata respectively. The calculated values of Chi-square were always greater than the table values.

The aggregated nature of leaf hoppers was confirmed by calculating dispersion indices. The results are presented in the Tables 2. and 2a.

Upper strata

The aggregated distribution of leaf hoppers was confirmed by more than 0.1 values of Cole Index of Dispersion during both rabi (0.27 to 0.55) and rabi-summer (0.13 to 0.27). The values of index of mean crowdiness ranged from 0.22 to 0.27 for rabi and 1.57 to 2.25 for rabi-summer. These values of index of mean crowdiness being always more than 1 for rabi-summer season, confirmed the aggregated distribution of leaf hoppers on upper strata.

Middle strata

The Cole Index of Dispersion values were in between 0.20 to 0.42 for rabi and 0.12 to 0.24 for rabi-summer. The values were never less than 0.1 indicating aggregated distribution. The values of index of mean crowdiness ranged from 1.01 to 3.20 for rabi and 1.12 to 2.91 for rabi- summer. These values of index of mean crowdiness were more than 1 in all the observations confirming the aggregated distribution of leaf hoppers on middle strata for both the seasons.

Lower strata

During rabi, the Cole Index of Dispersion values were in between 0.20 and 0.39 and during rabi-summer the values were 0.13 to 0.24. So, during both the seasons, the values were never less than 0.1, which indicated aggregated distribution. The values of index of mean crowdiness were more than 1 during rabi (1.54 to 3.40) and also in rabi-summer (1.55 to 5.10), which proved the aggregated distribution of leaf hoppers on lower strata for both the seasons.

The aggregated nature of thrips was confirmed by calculating dispersion indices. The results are presented in the Tables 3. and 3a.

Upper Strata

The values of Cole Index of Dispersion ranged from 0.13 to 0.32 forrabi season and 0.16 to 0.18 for rabi-summer season. As the values were always more than 0.1, it confirmed aggregated distribution of thrips. During both the seasons, the values of index of mean crowdiness were more than unity indicated aggregated distribution. The indices ranged from 1.32 to 4.00 for rabi and 2.87 to 5.31 for rabi-summer.

Middle Strata

During rabi, the Cole Index of Dispersion values were in between 13 to 0.32. The indices ranged from 0.15 to 0.18 for rabi-summer. The values were never less than 0.1 indicating aggregated distribution. The values of index of mean crowdiness ranged from 1.00 to 5.73 for rabi and 1.04 to 3.67 for rabi-summer. These values were more than 1 in all the observations, which proved the aggregated distribution of thrips on middle strata for both the seasons.

Lower Strata

During both the seasons, the Cole Index of Dispersion values were more than 0.1, which indicated aggregated distribution of thrips on lower strata. Thevalues ranged from 0.13 to 0.16 for rabi and 0.16 for rabi-summer. The values ofindex of mean crowdiness ranged from 0.51 to 2.93 for rabi and 0.45 to 0.60 for rabi-summer.

DISCUSSION

Studies on spatial distribution of sucking pests of sunflower indicated that the population of whiteflies fitted negative binomial model and the distribution was aggregated. Basso *et al*., (2001)also reported aggregated distribution of whiteflies.

Studies on intra-plant distribution established that the white fly population to be more on middle and upper strata. Similar results wereobtained by Basso *et al.,* (2001) and Men and Sarode (1999). Our studies also revealed that whitefly population was positively correlated to leaf moisture. Thus the preference of whiteflies towards more succulent upper and middle canopy compared to lower canopy is explainable.

Leaf hoppers have also exhibited aggregated distribution on sunflower and the population fitted negative binomial model. This is in consensus with the results obtained by Singh *et al.*, (1993).

Intra-plant distribution studies revealed that leaf hopper population preferred lower and middle canopy compared to upper canopy. Mahto (1990) and Singh *et al.,* (1993) also reported similar results. Studies between biophysical characters and leaf hopper population revealed that leaf hopper population was positively correlated to mid-rib thickness and thus it is evident that leaf hoppers prefer mature lower leaves with thicker mid-rib.

Thrips have shown aggregated distribution and negative bionomial model fitted the population pattern. Rathore and Tiwari (1999), Cho ki-Jong*et al.*, (2000) and Deligorgidis *et al.*, (2002) also presented similar reports.

Thrips showed preference towards upper and middle strata in the intra- plant distribution studies. Cho ki-Jong *et al.*, (2000) also obtained similar results. Thrips exhibited positive correlation towards leaf succulence and thus they preferred fresher succulent upper and middle leaves.

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Table 1: Variance-Mean Ratio (S^2/X) and Dispersion Indices for Whitefly Population on Sunflower (RABI)

Crop Age (DAS)	n	$\overline{X}$	S^2	$S^2 \sqrt{x}$	K_1	K_2	K_3	χ^2	X^1	Y^1	Cole Index	Index of Mean Crowdiness
UPPER STRATA												
35	30	3.07	4.43	1.41	7.38	8.50	4.54	13.22	8.77	15.77	0.14	3.74
42	30	3.37	4.74	1.41	7.88	8.56	4.94	33.23	9.71	16.28	0.15	3.82
49	30	4.30	5.73	5.73	12.88	6.52	7.29	72.95	17.39	28.58	0.14	4.89
56	30	3.36	4.30	4.30	21.02	6.52	7.73	187.12	10.71	15.20	0.17	3.80
63	30	0.90	1.81	1.81	0.88	3.86	6.95	31.93	0.69	2.40	0.24	1.02
COMMON K (K_c) = 0.60												
MIDDLE STRATA												
35	30	2.26	2.55	1.12	18.31	8.49	6.75	20.93	4.92	4.22	0.14	2.60
42	30	2.26	2.65	1.17	12.37	8.59	6.77	28.79	12.52	7.92	0.15	3.69
49	30	4.20	5.61	1.34	12.47	6.52	6.07	138.73	16.59	16.59	0.14	4.90
56	30	2.67	5.06	1.89	2.97	3.87	3.67	5.79	6.25	6.25	0.17	3.39
63	30	1.60	2.45	1.53	2.99	3.87	6.77	39.73	2.35	2.35	0.24	1.83
COMMON K (K_c) = 0.63												
LOWER STRATA												
35	30	2.85	4.25	1.40	7.35	6.54	7.32	12.21	8.50	14.87	0.14	3.10
42	30	1.90	2.71	1.42	4.43	6.52	3.57	12.44	3.36	5.46	0.15	2.43
49	30	3.97	4.80	1.20	19.10	6.53	4.00	177.53	14.97	18.90	0.14	4.96
56	30	2.43	5.01	2.06	2.29	3.87	6.56	19.90	5.08	22.69	0.17	2.80
63	30	0.97	1.62	1.67	1.43	3.87	3.63	45.50	0.85	1.66	0.24	1.23
COMMON K (K_c) = 0.51												

K_1 = Dispersion parameter (K); K_2 = K calculated from proportion of zeros; K_3 = K obtain from Trial and error method, n = No. of plants sampled.

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Table 1a: Variance-Mean RATIO (S^2/X) and Dispersion Indices for Whitefly Population on Sunflower (Rabi-Summer)

Crop Age (DAS)	n	$\overline{X}$	S^2	$S^2\sqrt{x}$	K_1	K_2	K_3	χ^2	X^1	Y^1	Cole Index	Index of Mean Crowdiness
UPPER STRATA												
35	30	0	0	0	0	0	0	0	0	0	0	0
42	30	2.39	3.06	1.27	8.62	8.33	3.70	8.21	5.44	6.96	0.21	3.04
49	30	1.00	1.37	1.37	2.63	7.75	6.25	21.53	0.93	0.90	0.16	1.16
56	30	2.10	3.47	1.65	3.21	7.75	7.43	43.83	4.00	9.95	0.16	2.38
63	30	1.73	3.51	1.02	1.67	7.90	5.63	47.31	2.59	10.60	0.18	2.04
COMMON K (K_c) = 0.45												
MIDDLE STRATA												
35	30	0.67	0.74	1.09	6.96	8.33	7.47	14.67	0.44	0.12	0.21	0.76
42	30	2.46	3.91	1.58	4.20	8.33	4.28	40.19	5.57	12.84	0.24	3.04
49	30	3.10	5.20	1.67	4.58	7.75	4.08	29.79	8.70	23.90	0.16	3.85
56	30	3.80	5.40	1.42	8.90	7.90	3.60	20.78	13.46	25.43	0.16	4.8
63	30	2.80	3.06	1.09	9.10	7.90	4.24	59.23	7.52	6.57	0.18	3.46
COMMON K (K_c) = 0.51												
LOWER STRATA												
35	30	0.16	1.38	1.18	6.23	8.33	7.38	29.89	1.29	0.75	0.21	1.32
42	30	1.80	3.06	1.70	2.56	7.75	7.94	13.20	2.92	7.75	0.24	2.02
49	30	1.90	2.50	1.32	5.94	7.75	4.18	35.81	3.40	4.38	0.16	2.35
56	30	1.23	1.56	1.27	4.59	7.90	6.40	26.45	1.43	1.21	0.16	1.42
63	30	1.90	2.98	1.57	3.31	7.99	6.38	62.69	3.31	0.18	0.18	2.19
COMMON K (K_c) = 0.58												

K_1 = Dispersion parameter (K); K_2 = K calculated from proportion of zeros; K_3 = K obtain from Trial and error method, n = No. of plants sampled.

Table 2: Variance-Mean Ratio (S^2/X) and Dispersion Indices for Leaf Hopper Population on Sunflower (Rabi)

Crop Age (DAS)	n	$\overline{X}$	S^2	$S^2_{\sqrt{X}}$	K_1	K_2	K_3	χ^2	X^1	Y^1	Cole Index	Index of Mean Crowdiness
UPPER STRATA												
35	30	0	0	0	0	0	0	0	0	0	0	0
42	30	0.20	0.23	1.17	1.16	4.51	6.87	2.12	0.03	0.14	0.55	0.22
49	30	0.20	0.58	2.90	0.10	5.14	4.00	14.16	0.03	0.14	0.27	0.25
56	30	0.24	0.38	1.58	1.61	4.54	5.78	10.10	0.03	0.17	0.370	0.27
63	30	0	0	0	0	0	0	0	0	0	0	0
COMMON K (K_c) = 0.20												
MIDDLE STRATA												
35	30	1.63	2.37	1.45	3.58	4.50	5.35	5.54	2.47	4.02	0.30	1.93
42	30	0.83	1.31	1.58	1.43	4.51	4.62	18.93	0.64	0.90	0.39	1.01
49	30	2.60	2.94	1.13	20.00	5.14	4.31	41.50	6.47	6.03	0.27	3.20
56	30	2.16	2.83	1.30	1.04	5.78	5.12	7.94	4.42	5.86	0.20	2060
63	30	2.74	2.97	1.08	5.43	4.71	4061	17.45	1.31	1.24	0.42	1.05
COMMON K (K_c) = 0.85												
LOWER STRATA												
35	30	2.16	3.17	1.46	4.64	4.54	5.98	10.80	4.36	7.93	0.24	2.52
42	30	1.36	1.48	1.08	16.24	5.14	7.96	3.15	1.79	0.82	0.39	1.54
49	30	2.23	2.80	1.27	8.71	5.14	7.15	69.92	4.72	5.63	5.63	2.55
56	30	2.86	5.77	2.01	2.82	5.78	5.36	36.77	7.10	30.48	30.48	3.40
63	30	2.36	4.65	1.97	2.44	5.78	5.52	52.71	4.88	19.29	19.29	2.79
COMMON K (K_c) = 0.35												

K_1 = Dispersion parameter (K); K_2 = K calculated from proportion of zeros; K_3 = K obtain from Trial and error method, n = No. of plants sampled.

Table 2a: Variance-Mean Ratio (S^2/X) and Dispersion Indices for Leaf Hopper Population on Sunflower (Rabi - Summer)

Crop Age (DAS)	n	$\overline{X}$	S^2	$S^2 \sqrt{X}$	K_1	K_2	K_3	χ^2	X^1	Y^1	Cole Index	Index of Mean Crowdiness
UPPER STRATA												
35	30	0	0	0	0	0	0	0	0	0	0	0
42	30	0	0	0	0	0	0	0	0		0	0
49	30	0	0	0	0	0	0	0	0	0	0	0
56	30	2.32	3.82	1.65	4.27	6.53	4.26	15.91	4.26	8.85	0.13	2.25
63	30	0.87	1.73	1.99	1.79	5.43	4.87	2.17	0.85	1.02	0.27	1.54
COMMON K (K_c) = 0.51												
MIDDLE STRATA												
35	30	0	0	0	0	0	0	0	0	0	0	0
42	30	0.93	1.37	1.47	1.97	5.13	4.97	2.71	0.80	0.95	0.24	1.12
49	30	2.23	3.28	1.47	4.72	6.35	7.62	15.19	4.62	8.58	0.12	2.52
56	30	2.60	4.66	1.79	3.27	7.72	7.15	18.59	6.03	19.13	0.14	2.91
63	30	1.86	3.15	1.69	2.70	7.72	4.46	31.03	3.15	8.08	0.17	2.28
COMMON K (K_c) = 0.34												
LOWER STRATA												
35	30	0	0	0	0	0	0	0	0	0	0	0
42	30	1.36	2.10	1.53	2.53	6.35	7.42	2.79	1.72	3.05	0.24	1.55
49	30	4.03	8.58	2.12	3.57	6.35	4.39	25.73	13.81	69.99	0.13	4.95
56	30	4.03	5.96	1.47	8.42	7.72	3.78	22.40	15.08	31.54	0.14	2.91
63	30	3.06	7.85	2.56	1.96	7.72	7.85	57.84	7.34	58.63	0.16	3.45
COMMON K (K_c) = 0.23												

K_1 = Dispersion parameter (K); K_2 = K calculated from proportion of zeros; K_3 = K obtain from Trial and error method, n = No. of plants sampled.

Table 3: Variance-Mean Ratio (S^2/X) and Dispersion Indices for Thrips

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Population on Sunflower (Rabi)

Crop Age (DAS)	n	$\overline{X}$	S^2	$S^2 \sqrt{x}$	K_1	K_2	K_3	χ^2	X^1	Y^1	Cole Index	Index of Mean Crowdiness
UPPER STRATA												
35	30	3.26	6.05	1.85	3.81	7.94	4.38	18.88	9027	33.29	0.13	4.00
42	30	2.90	5.68	1.96	3.03	7.94	6.00	93.19	7.33	29.35	0.17	3.38
49	30	2.23	2.94	1.31	7.02	5.09	4.61	77.19	4.69	6.43	0.16	2.71
56	30	3.26	4.13	1.26	12.31	5.09	4.96	160.16	10.10	13.81	0.17	3.92
63	30	1.16	1.79	1.54	2.15	7.12	7.60	27.81	1.25	2.06	0.32	1.32
COMMON K (K_c) = 0.38												
MIDDLE STRATA												
35	30	5.03	10.65	2.11	4.50	7.94	7.25	43.74	21.55	108.47	0.13	5.73
42	30	4.33	4.71	1.09	49.50	7.94	4.27	142.58	18.03	17.87	0.16	5.34
49	30	3.96	7.75	1.95	4.15	5.09	6.55	151.22	13.72	56.21	0.16	4.57
56	30	2.16	4.07	1.88	2.46	7.12	7.10	14.05	4.14	14.43	0.17	2.47
63	30	0.80	1.47	1.84	0.94	7.12	3.10	47.67	0.56	1.38	0.32	1.00
COMMON K (K_c) = 0.29												
LOWER STRATA												
35	30	0.43	0.74	1.70	0.62	7.94	5.94	52.43	0.17	0.11	0.13	0.51
42	30	2.50	6.95	2.77	1.40	5.10	5.75	59.28	4.64	45.78	0.16	2.93
49	30	0	0	0	0	0	0	0	0	0	0	0
56	30	0	0	0	0	0	0	0	0	0	0	0
63	30	0	0	0	0	0	0	0	0	0	0	0
COMMON K (K_c) = 0.58												

K_1 = Dispersion parameter (K); K_2 = K calculated from proportion of zeros; K_3 = K obtain from Trial and error method, n = No. of plants sampled.

Table 3a: Variance-Mean Ratio (S^2/X) and Dispersion Indices for Thrips Population on Sunflower (Rabi - Summer)

Crop Age (DAS)	n	$\overline{X}$	S^2	$S^2_{\sqrt{X}}$	K_1	K_2	K_3	χ^2	X^1	Y^1	Cole Index	Index of Mean Crowdiness
UPPER STRATA												
35	30	2.50	3.50	1.40	6.25	6.42	6.73	10.74	5.84	9.75	0.16	2.87
42	30	2.87	6.12	2.13	2.52	6.42	5.03	77.28	6.97	34.58	0.17	3.44
49	30	4.26	4.40	1.03	7.72	7.06	6.64	13.21	17.55	15.17	0.16	4.91
56	30	4.73	9.72	2.05	4.49	7.06	8.00	38.49	19.25	89.73	0.15	5.31
63	30	4.03	4.24	1.05	7.86	7.69	4.08	20.58	15.66	13.96	0.18	5.02
COMMON K (K_c) = 0.40												
MIDDLE STRATA												
35	30	2.75	4.76	1.73	3.80	6.42	7.35	24.07	6.82	19.90	0.15	3.13
42	30	3.10	5.96	1.96	3.36	6.42	5.43	136.44	8.43	32.37	0.17	3.67
49	30	1.80	2.72	1.51	3.53	7.10	6.22	25.80	2.99	5.58	0.16	2.09
56	30	0.90	2.23	2.47	0.61	7.69	6.55	16.47	0.64	4.07	0.15	1.04
63	30	1.40	2.24	1.60	2.31	7.70	4.50	34.19	1.79	3.65	0.18	1.17
COMMON K (K_c) = 0.31												
LOWER STRATA												
35	30	0.53	1.08	2.03	0.51	6.42	7.19	44.04	0.24	0.64	0.16	0.60
42	30	0.40	0.87	2.17	0.34	7.06	7.10	4.00	0.13	0.35	0.16	0.45
49	30	0	0	0	0	0	0	0	0	0	0	0
56	30	0	0	0	0	0	0	0	0	0	0	0
63	30	0	0	0	0	0	0	0	0	0	0	0
COMMON K (K_c) = 0.37												

K_1 = Dispersion parameter (K); K_2 = K calculated from proportion of zeros; K_3 = K obtain from Trial and error method, n = No. of plants sampled.